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An ontology-based semantic service for cooperative urban equipments

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ABSTRACT

The development of SOA (service oriented architecture) applications is a paradigm to consider for the integration of services which usually requires the incorporation of distributed artificial intelligence technologies or multi agent systems (MAS) to achieve their objectives. This is the case of transportation field, where the improvement of urban data networks and embedded systems allow the implementation of complex distributed services based on intelligent transportation systems. One of the challenges of this kind of systems is the discovery of services. Typically, discovery of services lacks of intelligence, or the result of this process returns a lot of nonsense information. However, the field of transportation requires quick and accurate requests and answers to deal with emergencies or incidents in the traffic flow. For this purpose, this paper proposes the development of a specific service called semantic service (an ontology-based semantic communication service) developed in TAO (The ACE ORB) of CORBA (common object request broker architecture). This service is able to provide a communication support for distributed environment in conjunction with a set of base libraries like Redland (RDF language bindings) for interacting with ontologies written in RDF and RDFS format. A parser Raptor (RDF Syntax Library) is used for analyzing sequences of symbols to determine the grammatical structure, and a syntax query language, Rasqal (RDF Query Library) is used to build and execute queries. Both, Raptor and Rasqal were designed to work with the Redland library. The main objective is to manage ontological information and interoperate with implemented services in embedded urban devices. Obtained results demonstrate the feasibility and effectiveness of the proposed approach.
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1. Introduction

The urban traffic control is extremely complex and dynamic. Metropolitan and rural areas are changing rapidly with the evolution of information and communications technologies (ICT), which calls for better organization and knowledge management. Intelligent infrastructure development in these areas are currently explored and extended by analyzing the adaptability of developed tools to the continuous changes that occur in the setting of ITS (intelligent transportation systems), considering new technologies, innovation of mobility and sustainable systems (Esteve et al., 2007).

The real-time traffic parameter estimation and control operations are a challenge for control of urban traffic systems (Choy et al., 2003). The current UTCS (urban traffic control systems) are usually based on centralized networks (Chen et al., 2008). However, current control systems are demanded to manage undesirable changes in traffic flow such as accidents, and be able to optimize the flow by adjusting traffic signals and coordinate operations for each signal (Toral et al., 2011).

In this context, the ITS can share information and operate in large collaborative environments. For example, an incident management system in urban environments can directly influence on emergency response, providing timely and accurate information on the incident and the seriousness of the case. However, in most cases, the heterogeneous information does not provide the necessary data to fulfill certain tasks. The information shared and common understanding can sometimes be confusing, leading to accidents, delays and chaos in the urban traffic, depending on the area to be implemented. In fact, one of the main challenges in the design and operation of ITS is to provide users a complete and transparent formal environment regardless of the characteristics and capabilities of the components connected to the system. The intelligent location of services and information is probably one of the most known problems in the ITS. The dynamic discovery of information, composition and invocation of services through intelligent agents represent a potential solution to these problems. For this purpose, devices and applications from different suppliers and vendors need a flexible way to work collaboratively with each other. They should be able to discover services autonomously, coordinate their work, resolve conflicts based on critical situations, negotiate with users; in essence, they should be

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able to adapt to changes in the environment itself. Rockl and Robertson (2010) argue that the success of cooperative ITS applications is mainly in exchanging information between distributed nodes. According to them, the transmission of large flows of information contrasts with the limited bandwidth of the channels that tend to be shared by all nodes participating in the ITS. They propose that the solution lies mainly in the cooperative commitment to select relevant pieces of information for dissemination according to its value.

Technologies such as distributed artificial intelligence and multi-agent systems (MAS) have gained considerable importance due to their ability to solve complex real world problems (Balaji and Srinivasan, 2010), using a collection of collaborative agents which interact with each other to achieve common and individual goals (Li et al., 2006; Chen and Cheng, 2010). However, in heterogeneous situations like urban environments, distributed systems are well known for their difficulty to interoperate between agents, which make it grow interest on unified software platforms and standard implementations protocols (Wang et al., 2006).

SOA is presented as an attractive alternative to enable interoperability of systems and reuse of resources. It can serve as underlying support for MAS applications in distributed and heterogeneous systems (Wang et al., 2010; Suri et al., 2007). To implement SOA systems, two main technologies stand out, WebServices and CORBA. The core of WebServices is SOAP (simple object access protocol) communication protocol based on XML (extensible markup language) to integrate services. But processing large SOAP messages would reduce significantly the system performance, causing bottlenecks (Tekli et al., 2012). The common object request broker architecture (CORBA) provides object reference and interface semantics so that method invocations between objects written in different programming languages or executing on different end systems are performed transparently through a set of object request brokers (ORBs) (Gill, 2006).

SOAP communication produces high network traffic causing high latency compared to CORBA. This represents a central problem, specifically in wireless communication networks (Phan et al., 2008). While Web services are presented at times as more flexible compared to CORBA, they are still at an early stage compared to CORBA. In practice, SOA-based applications are not always successful because most of them are made on an ad-hoc based primarily on personal experiences (Guo et al., 2010). Although companies are increasing their dependence on SOAs, these systems are still in a nascent stage, immature and with large security problems (Kabbani et al., 2010). Unquestionably CORBA does not offer the same as SOA promises, but is presented as the best subset of tools to support what SOA "tries to be". CORBA is a mature technology that includes the most important services, as the naming service and the event service and more. The location of the information or a specific service may be, for example, through a CORBA trading service, where representation would be given by pairs of name/value and their properties cover the reference to the service itself, descriptively. A trader acts as a database that stores references to objects that are described by their properties (Henning and Vinoski, 1999).

Recent publications has begun to propose new architectures for ITS. Chen et al. (2008) presented the design and implementation of a framework for public transport. They include a mechanism for collection of data through Web services, the incorporation and composition of schemas for route planning. MAS-based approaches have been adopted in various transportation management systems (Chen and Cheng, 2010), particularly in traffic and bus management. Fernandez and Ossowski (2011) support the premise that the use of MAS allows a decoupled design and implementation of different modules (agents), thus promoting reuse. They also show the study on a multi-agent architecture, service-oriented for the construction of advanced DSSs (decision support systems) for transportation management. They show how different dialogues between DMs (decision makers) and the system itself can be modelled in terms of organizational concepts through taxonomies of roles and types of interactions. Terziyan et al. (2010) presented a focus on requirements and architecture necessary for traffic management systems, showing how such a system can be beneficial from the semantic point of view through technologic agents but at the same time wondering how to combine them with the data processing and automated tools. However, none of the above approaches takes advantage of the service oriented paradigm or the dynamic selection of services. The main problem remains in working with the information between these services: how to find services that meet real needs, how to trust that the data received/sent are reliable or which techniques and mechanisms implemented on the ITS meet a real environment.

The application of traditional search mechanisms, based on basic properties, can lead to inefficient results. The search for a particular service should be done intelligently. There should be a mechanism of differentiation and weighting of information. Customers who make requests on a particular service need to be able to gain some level of truth and confidence about a particular service. They must be able to take decisions of convenience between services in order to obtain the best results. Customers require some intelligence in the search. Trading services are unable to provide this level of intelligence. Some approaches in the design and implementation of a CORBA trading service do not address the main problems of finding services or large transfers of information in distributed systems, triggering large performance and scalability problems (Craske and Tari, 1999; Zhu et al., 2005).

In recent years, the incorporation of ontologies has increased, above all in semantic Web sites, enabling interoperability of heterogeneous data (Zhao et al., 2009; Xue et al., 2012). The incorporation of ontologies implemented in a standardized set of concepts such as RDF (resource description framework) (W3C Members, 2004a) extended by class and properties specification mechanisms as RDFS (RDF-Schema) (W3C Members, 2004b) and a service that manages ontologies in a cooperative way, would play an important role in ITS-oriented environment. This paper proposes the development of an SS (semantic service) implemented in TAO CORBA, and ready to run on different processors such as SPARC, AMD, Intel, ARM, PA RISC (32/64 bit), etc., and operating systems like Solaris, Windows, Linux, HP-UX, IBM, Mac OS, etc. The SS will use ontologies mainly based on theories of knowledge and natural language processing. The different traffic services, mostly implemented on devices with embedded architectures, interoperate with the SS who will be responsible for providing and managing all the information of the C/S (client/server) architecture, and intermediate between them in a dynamic and intelligent way. The SS will use cooperative transaction data from the time of collection of information by automating decision-making in situations that require intelligent intervention of the urban environment.

The rest of the paper is structured as follows: Section 2 presents the developed ontologies on intelligent transportation systems field. Section 3 explains the proposed semantic service architecture and implementation. The details about the implementation of the semantic service in TAO CORBA are included in Section 4, followed by the obtained results in Section 5. Finally, conclusions are discussed in Section 6.

2. Ontologies on intelligent transportation systems

The use of ontologies can substantially reduce the failure rate when searching services in scenarios like urban environments,

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